LBNL–Agilent Partnership Overcomes Barriers to Solid-State Light Sources

Key Discoveries Aid Development of Large-Scale Lighting Applications

A three-year cooperative research and development (CRADA) project involving researchers at Berkeley Lab and Agilent Technologies (formerly Hewlett-Packard) is approaching a successful conclusion. Basic research has solved issues impeding the development by Agilent of high efficiency solid-state light sources. These new light emitters have the potential to replace incandescent lighting on a large scale with a resulting quantitative increase in energy efficiency.

Agilent Technologies is the world's largest manufacturer of efficient, light-emitting diodes. Until recently such diodes could be fabricated to emit light only in the spectral region from the far infrared to green. Recent progress with group III-nitrides and their alloys has changed this situation fundamentally because these materials can emit light in the green, blue, violet, and ultraviolet regions of the spectrum. There have been, however, basic materials problems associated with the development of group III-nitrides (especially the $In_xGa_{1-x}N$ alloy) for these applications; these problems have proved to be a most fertile ground for cooperative research between Berkeley Lab and Agilent.

The LBNL/Agilent CRADA focused on two major materials issues and drew upon the Berkeley Lab’s capabilities developed over years by funding from the Materials Sciences Division of the Department of Energy, Office of Basic Energy Sciences. The first issue involved the growth of an essential component of the diode, the heavily Si-doped “n-type base contact.” This layer was prone to cracking if grown thicker than 2 microns. Joint CRADA work identified the mechanism responsible for the tensile stresses that cause the film to crack during growth and led to a modified growth scheme that reduced cracking and increased production device yield.

The second issue involved the understanding and control of the light emission process. When the CRADA was initiated, it was not known which of several competing theories correctly explained the mechanism by which light is emitted from the “active” InGaN layer in the LED structure. By performing optical studies using high-pressure diamond anvil cells, the LBNL workers showed that the emitted light originates from localized, In-rich areas of InGaN layer. This is because recombination of the electrons and holes that produces light in an LED is particularly efficient in these areas. This partially explains why III-V-nitride based LEDs can be so efficient in spite of the large density of structural defects they contain. These scientific studies have assisted Agilent researchers and engineers in making excellent progress in the design, development and fabrication of efficient, long-lived LEDs.

Recently HP announced the founding of another new company, LumiLeds Lighting, jointly with one of the world's leaders in the lighting sector, Philips Corp. The new company has the amibitious goal of replacing incandescent lighting with solid state sources, creating enormous new markets and great energy savings. Thus, what were once believed to be bold predictions regarding area and space illumination with solid state lamps (i.e. LEDs) may soon become a reality. Through this CRADA, therefore, DOE was able to sponsor basic research in support of a US company that may lead to a completely new family of products with a potentially significant impact on US energy consumption.

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W. Shan, P. Perlin, J. W. Ager III, W. Walukiewicz, E. E. Haller, M.D. McCluskey (Agilent Technologies), N. M. Johnson (Agilent Technologies), and D.P. Bour (Agilent Technologies), “Pressure dependence of optical transitions in $In_{0.15}Ga_{0.85}N$/GaN multiple quantum wells,” Phys. Rev. B 58, 10191-10194 (1998).

W. Shan, J. W. Ager III, K. M. Yu, W. Walukiewicz, E. E. Haller, M. C. Martin, W. R. McKinney, and W. Yang (Honeywell), “Dependence of the fundamental band gap of $Al_xGa_{1-x}N$ on alloy composition and pressure,” J. Appl. Phys. **85**, 8505-8507 (1999). L. T. Romano (Xerox), C. G. Van de Walle (Xerox), J. W. Ager III, W. Götz (Agilent Technologies), and R. S. Kern (Agilent Technologies), “Effect of Si doping on strain, cracking, and microstructure in GaN thin films grown by metalorganic chemical vapor deposition,” J. Appl. Phys., submitted.